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SHAFT SINKING BY DIAMOND DRILLING
BELLEFONTE MINE, NATIONAL GYPSUM CO.
CENTRE COUNTY, PA.

BY

McHENRY MOSIER

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SHAFT SINKING BY DIAMOND DRILLING, BELLEFONTE MINE, NATIONAL GYPSUM CO., CENTRE COUNTY, PA.[1]

By McHenry Mosier[2]

INTRODUCTION AND SUMMARY

The diamond-drill method was tried at the site selected for driving a 5- by 6-foot air shaft at the east end of the Bellefonte mine. This method of sinking consisted, first, of drilling a 5-3/4-inch-diameter cut hole from the surface, then drilling parallel 1.5-inch (EX) holes around it at appropriate distances for a balanced blasting round. The cut hole was not charged with explosive but served as a relief chamber for the incipient expansion of the ground broken by blasting the surrounding 1.5-inch holes. The length of each hole was 236 feet, which was the finished depth of the shaft.

The nature of the work in the air shaft was largely experimental, and many difficulties arising from the lack of special equipment and proper technique for precise alinement of the drill holes caused expensive delays before they could be overcome. Drilling the 5-3/4-inch hole, which was impeded by frequent core blocks in the core barrel, required 10 shifts. The average advance per shift for an EX hole was about 150 feet.

The holes were charged and fired from the surface. The length of the section blasted in one cycle was 10 feet. Blasting progressed from the bottom of the shaft upward. The broken stone dropped into a chute, from which it was drawn into cars on the haulage level.

The Bellefonte mine is an underground limestone mine.[3] The primary objective in undertaking the research on shaft sinking by diamond drilling was to perfect a method for driving connections between levels of the mine.

CONCLUSIONS

The diamond-drill method has proved feasible and, with improvements suggested from the experience gained in the air shaft, will be used as

1/ The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7477."

2/ Chief, College Park Branch, Mining Division, College Park, Md.

3/ Mosier, McHenry: Diamond Drilling Blast Holes, Bellefonte Mine, National Gypsum Co., Centre County, Pa.: Bureau of Mines Inf. Circ. 7438, March 1948, 6 pp.

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standard practice for driving 300-foot raises that are accessible at the top for diamond drilling and at the bottom for removal of broken stone.

At the experimental air shaft the actual cost of diamond drilling holes from the collar of the shaft and blasting 10-foot sections from the bottom was somewhat greater than the conventional method of raising from a mine level, but improved procedures should make the costs of the diamond-drill method competitive with those of conventional methods under conditions prevailing at the Bellefonte mine.

Additional advantages are safety and speed. In the usual methods of mine development, a serious hazard always is presented when the miner first enters the top of the raise to bar down after blasting. The diamond drill has eliminated this hazard and has increased the over-all speed in driving such headings.

As a result of experience gained in the air shaft, the following improved procedures are planned as standard practice for driving mine raises:

1. All loose rock will be removed at the drill site, at the top of the raise. This may entail some blasting.

2. A concrete sill 10 by 10 feet in plan and at least 3 feet thick will be poured as a base for the diamond-drill rig.

3. A portable template constructed from structural steel bolted to the concrete base will support the diamond-drill rig.

4. The diamond drill will be mounted on posts or jigs built into the template at the collar of each drill hole. These posts or jigs will maintain parallel set-ups for the drill with respect to azimuth. The head of the drill will be set on the proper inclination before drilling starts. This setting will not be changed but will be maintained at each hole.

5. Use of a hydraulic feed instead of a gear feed on the diamond drill, which should increase the rate of penetration in the Bellefonte ledge.

In comparison with the experimental job at the air shaft, the preparatory work and procedure, as outlined above, should materially expedite diamond drilling by increasing the rate of penetration and the accuracy in alinement of drill holes. The improved procedures should make costs competitive with those of conventional methods under conditions prevailing at the Bellefonte mine.

ACKNOWLEDGMENTS

The material for this Information Circular was supplied by Keith W. Waugh, works manager, and his staff at the Bellefonte mine, National Gypsum Co., in April 1948. This method of shaft sinking has been used on a small

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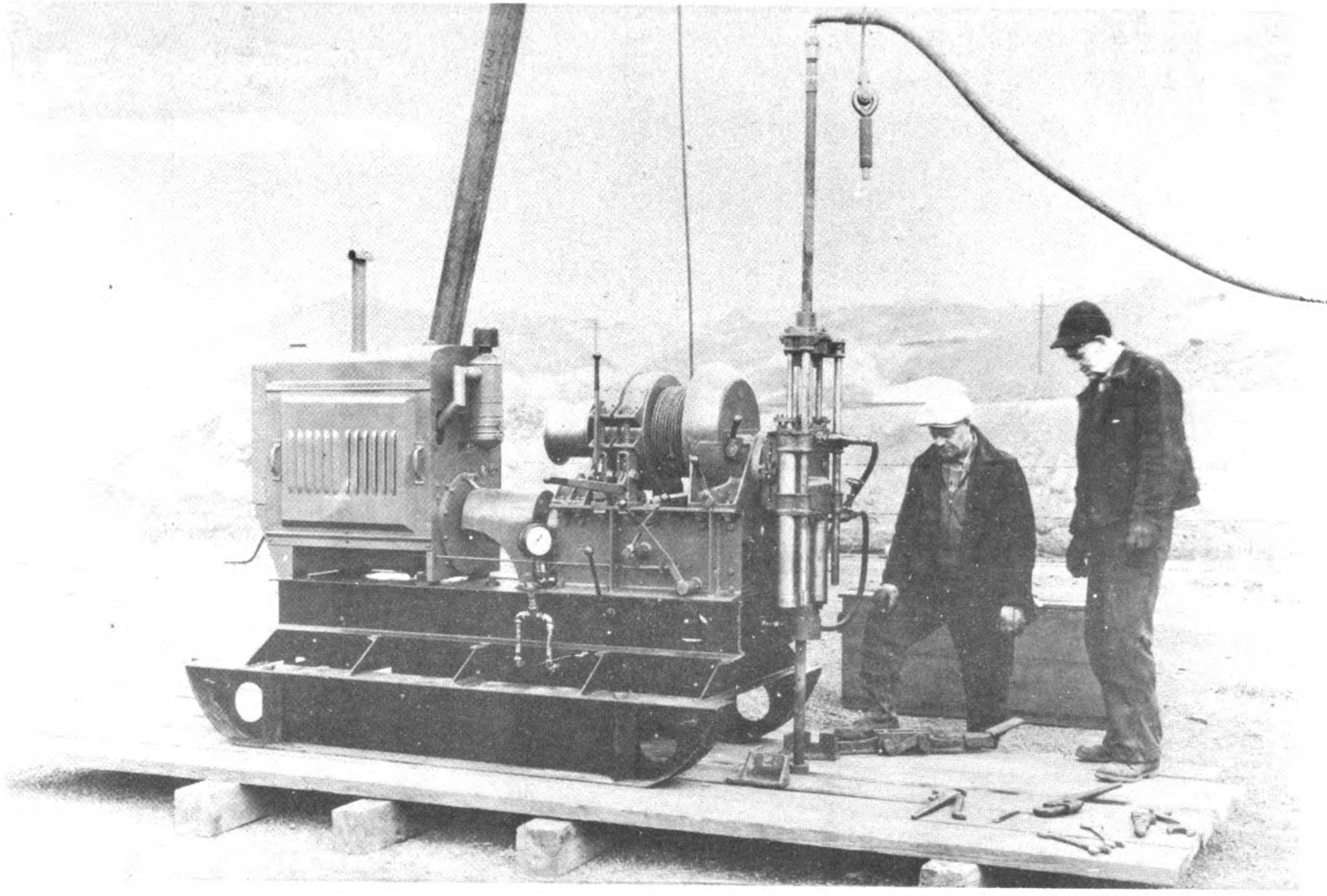

Figure 1. - Diamond-drill rig.

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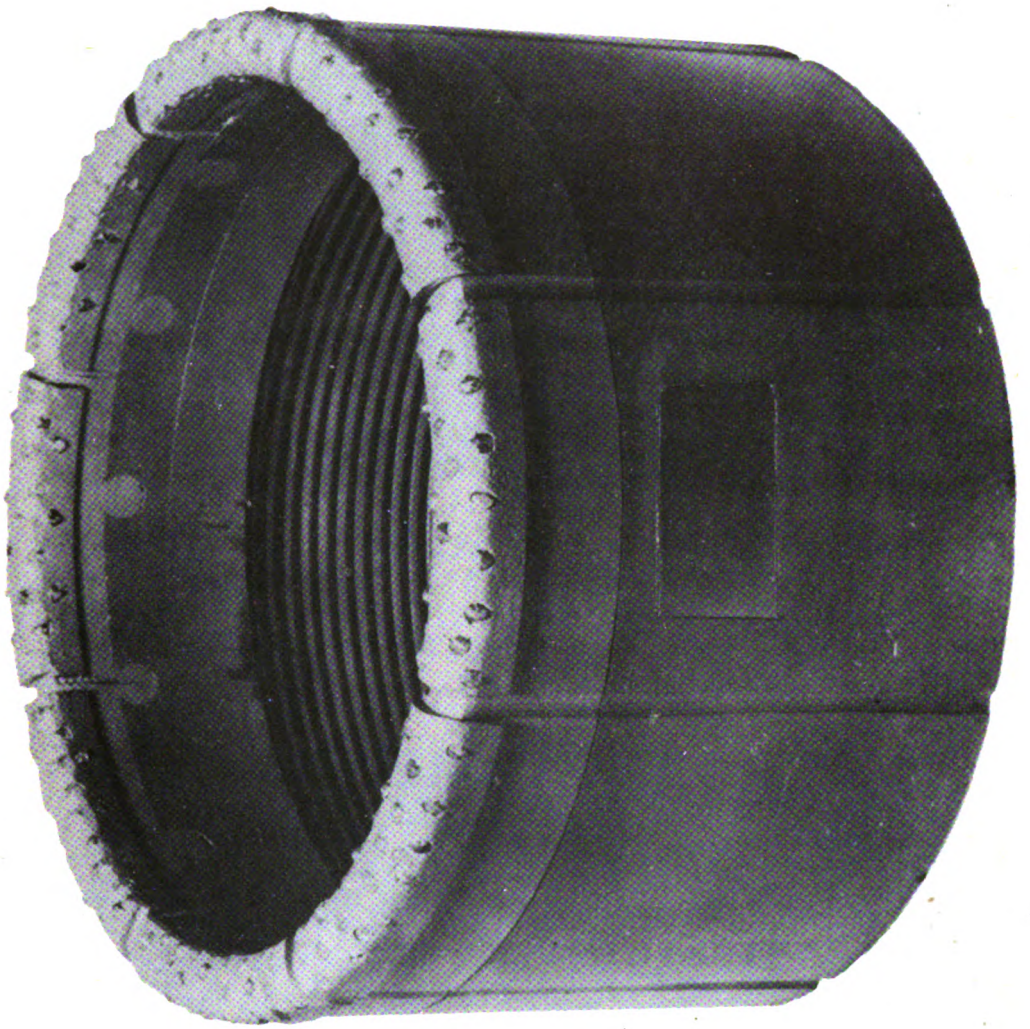

Figure 2. - 5-3/4-inch bit.

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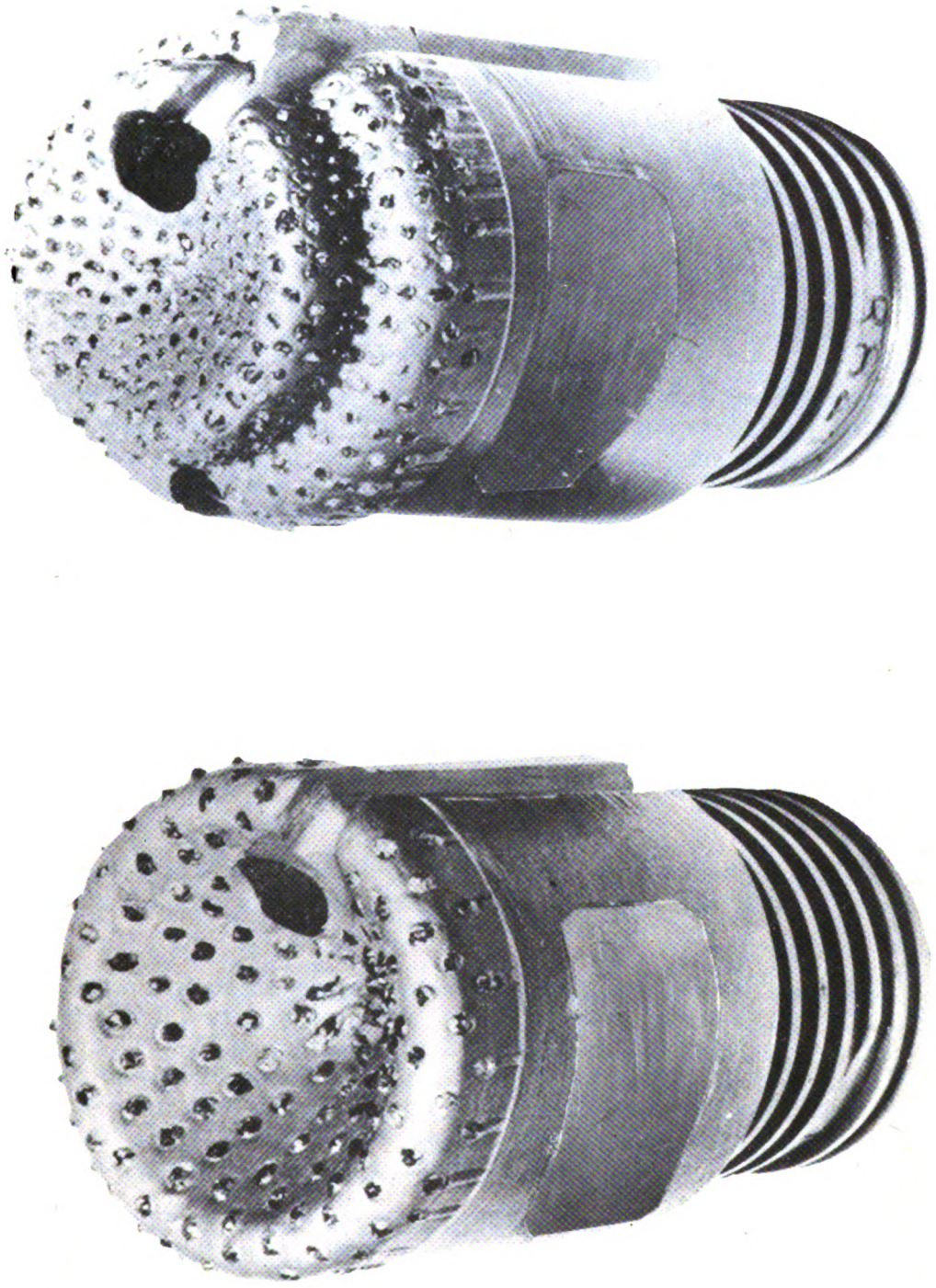

Figure 3. - Noncoring EX (1.5-inch) bits.

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scale in the West, notably at the National Tunnel & Mines Co. in Utah. The work at the Bellefonte limestone mine has added refinements to the method, suggested improvements, and indicated its application, under certain conditions, to driving 300-foot raises.

Photographs of the diamond-drill rig, 5-3/4-inch bit, and EX (1.5-inch) bits (figs. 1, 2, and 3) were furnished through the courtesy of James A. Ross, president, Sprague & Henwood, Inc., Scranton, Pa.

SHAFT SINKING

General Conditions

The Bellefonte mine is opened to the 330-foot level on a limestone ledge 55 to 70 feet thick that dips 72°. The air shaft follows this dip as closely as it was possible to aline the drill holes. The ledge is a very pure high-calcium limestone containing 98.5 to 99.0 percent $CaCO_3$ with small variation in composition or structural characteristics. The weight of the stone in place is 160 pounds per cubic foot. The shrinkage method of stoping is employed, stopes 300 feet long being separated by 40-foot pillars.[3/] The present stoping lift ranges from 150 to 190 feet. A new level will be driven 300 feet below the 330-foot haulage level.

The air shaft was not required to satisfy any immediate urgency but was to be used for ventilation, for which the leeway in time was ample. It was put on surface to match a regular man raise in the center of a 40-foot pillar between stopes. A truck road ran within 300 feet of the collar of the air shaft.

The diamond drilling in the shaft was done on contract. The contractor furnished all drilling equipment and cleared the drill site of soil and loose rock.

The drilling equipment comprised the normal, standard, heavy-duty, screw-feed core drill with a capacity of 1,750 feet of EX hole (1.5-inch diameter) (fig. 1). It was driven by a 30-horsepower gasoline engine. The 5-3/4 inch bit was a cast set coring bit (fig. 2). The EX (1.5-inch) bits were noncoring cast set bits, some of which were concave and some were the pilot type (fig. 3). A 5-foot core barrel was used with the 5-3/4-inch bit and a 10-foot core barrel with the EX noncoring bits.

Water for drilling was available in the low end of the old quarry in which the shaft was situated. Drilling was performed by a crew of two men, who worked one shift a day, 5 days a week.

Diamond Drill Set-Up

After the soil and loose rock had been removed, the standard surface set-up was used, wherein the machine mounted on steel skids was lag-screwed into three wooden sills about 12 by 15 inches in cross section and 12 feet in length. Each hole was independently alined for azimuth and inclination.

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The old quarry was 30 feet in width at the drill site. The azimuth of the holes was marked by pins set in the walls of the quarry, 6 feet above the floor. A string was then pulled taut between these pins. Two 10-foot E rods inserted through the chuck in the drill were swung to a horizontal position and turned to the line established by the string, and the plumb bobs suspended from it.

The drill rod at each hole was then set on the 72° inclination by means of a clinometer comprising a 2-foot steel straight edge and a machinists protractor with built-in level. The straight edge was placed along the axis of the drill rod, which was then inclined until the level on the protractor was horizontal at the 72° mark.

Considerable trouble developed in alining holes owing to the continual settling of the diamond-drill rig, which had to be wedged back to position each morning.

A wooden template constructed of 2-inch plank was laid on the drill site with the position of the collars of all holes marked on it. To facilitate starting the holes in the proper direction, small patches or areas of concrete were used to fill irregularities in the rock at the collars of the several holes. A rich mix was used, some patches utilizing aggregate and others consisting entirely of neat cement. Thus, a smooth surface was presented for collaring the holes.

Diamond Drilling

The position of the drill holes is shown in the drilling chart (see fig. 4), on which the EX holes are plotted in relation to the collar and bottom of the 5-3/4-inch cut hole. The 5-3/4-inch center cut hole was drilled first. The first EX hole was inaccurately alined for both azimuth and inclination. Holes 2, 3, and 4 were precisely alined for inclination but were not compensated for the apparent deviation of the cut hole. Hole 4 connected with the cut hole at 145 feet where it was bottomed. Hole 5 was perfectly compensated for the deviation of the cut hole but was inaccurately alined for inclination. Deviations in the remaining holes were due to lack of proper facilities and instruments for starting and drilling on the required course, as well as the lack of stable foundations for the diamond-drill rig.

Holes 17, 18, 19, and 20 could not be reached at the bottom without undue expense, so only the collars are shown in the chart (fig. 4). Sections of all holes drilled were usable for blasting, but some of these sections were at lower levels and others at higher elevations. In future work the standard round for a 5- by 6-foot opening will comprise 12 holes.

In the Bellefonte ledge an EX bit drilled a straighter hole than the 5-3/4-inch bit. This may have been due to the use of a 5-foot core barrel and B rods (approximately 2 inches in diameter) with the large bit, whereas the 10-foot core barrel and the E-rods (1-5/16 in. diameter) on the EX bit formed a more effective support and guide for drilling the small holes.

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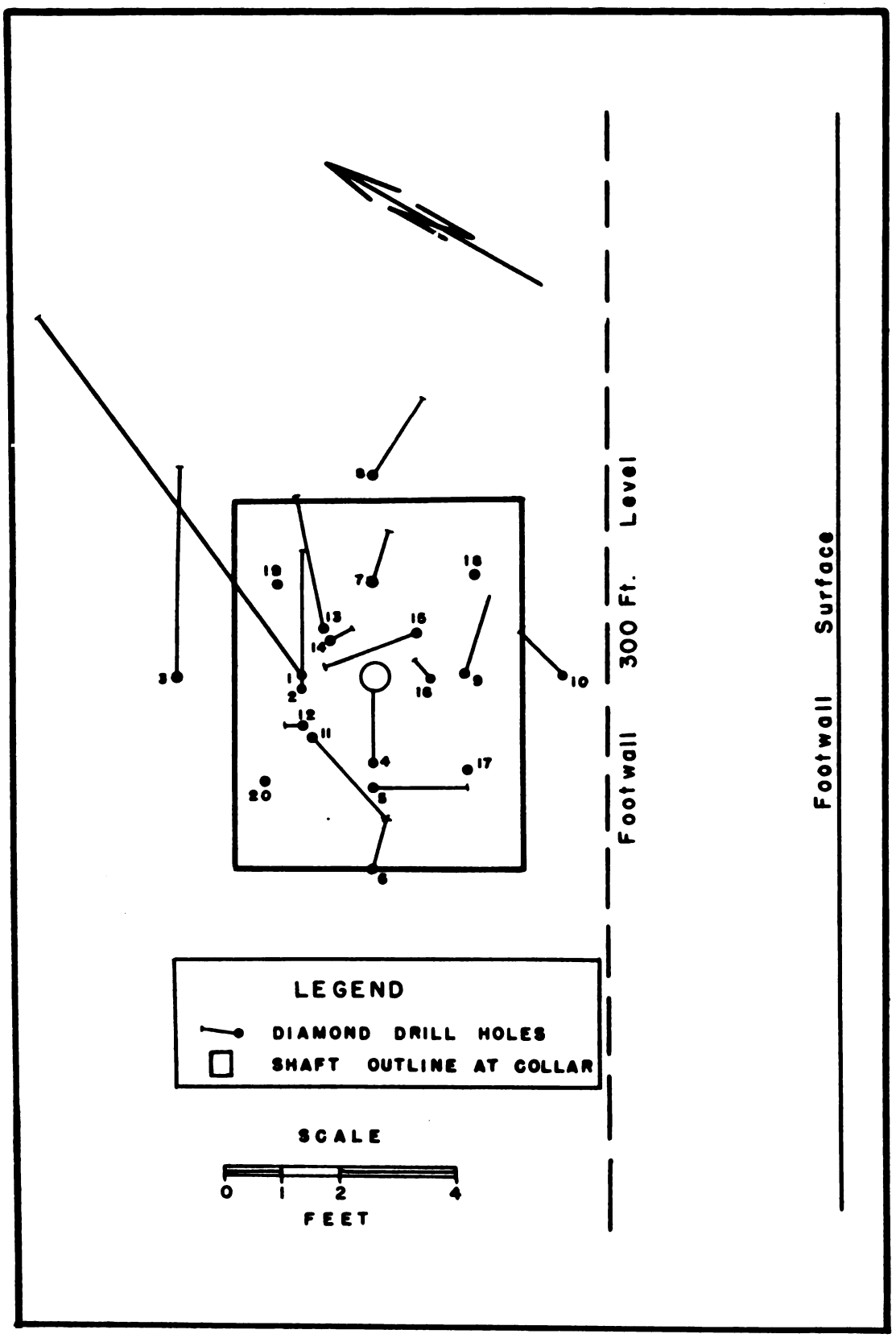

Figure 4. - Drilling chart.

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Loading Explosives

The 1.5-inch holes only were loaded with explosive. The 5-3/4-inch central cut hole was not charged, because it served as a relief chamber by affording enough space for the incipient expansion of the rock to allow the ground to break when blasted.

The first loading and blasting was done from the bottom of the shaft. As the shaft was advanced upwards, pillar crosscuts were driven at 25-foot vertical intervals. This method continued to the uppermost pillar crosscut at 155 feet above the haulage level. From this elevation to the surface, a distance of 75 feet, loading was performed from the surface.

In loading the holes, a 4-inch section of 1-inch drill steel was lowered from the surface and used to plug the hole at the bottom to prevent the dynamite from dropping into the open space below. This plug was fastened to a small-diameter wire. The bottom of the hole was found by the "feel" in lowering the plug. One man held the plug in position while another loaded the hole. A handful of dirt was dropped in the hole to cover the iron plug, then two cartridges of dynamite (1-1/4 by 8 inches), after being slit, were placed in the hole and tamped with a solid brass rod 1 inch in diameter and 2 feet in length, which was fastened to a 1/4-inch braided cotton rope with wire center. Then two additional sticks were tamped in the hole. This operation was repeated until the charge of 14 sticks was completed.

The primer was usually placed below the two top cartridges in the charge. Sixty-percent semigelatin dynamite with no stemming was used. The consumption of dynamite was thus 9.5 pounds per foot of advance in the shaft.

Loading 15 holes in a 10-foot round required 1 hour.

Firing

Electric blasting caps were No. 6 strength, usually with three delays, such as 0, 3, and 6 or a similar combination. Fourteen or fifteen holes were fired in a round. Four or five holes nearest the cut hole were fired in the first group, about six holes adjacent to the first group were fired next and the remaining exterior holes in the third group. After shooting the first two delays, the rock shattered and jammed in place and did not fall until the outside holes were fired on the third delay.

The number of rounds that can be blasted in a shift depends in a large measure on the efficiency of the mine ventilation.

The standard section (length of round) blasted was determined by trying lengths of 5, 7, 10, 12, and 15 feet. The 15-foot round jammed and plugged the shaft. This jam was removed by firing 20 sticks of dynamite in the cut hole. Three 12-foot rounds were loaded, but each pulled only 10 feet. As the 10-foot rounds consistently pulled 10 feet, this became the standard section for blasting.

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The diameter of the central cut hole is always a compromise between two factors. With a large diameter-cut hole, a longer round can be broken to better advantage, but the expense of drilling the large cut hole is greater.

Disposal of Broken Stone

The broken stone from the shaft dropped into a chute on the haulage level, whence it was drawn directly into cars.

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